The Dynamical Life of Interstellar Filaments

The role of gas dynamics, stellar feedback and chemistry

B. Körtgen, M. Jung, R. Banerjee, Hamburger rotational pattern, it is primarily the more diffuse re-Sternwarte, Universität Hamburg gion surrounding the filament hub, which is affected.

In Short

- Stars form in dense prestellar cores that are deeply embedded in gas filaments.
- We use high-resolution numerical simulations achieving resolutions of a few AU.
- Low-mass star feedback via radiation appears too weak to influence the global dynamics of the filaments.
- Bulk rotational motions are shown to only affect the lower density gas.
- With time, overdensities, which are initially well separated, are seen to merge.

Star formation occurs in dense pre-stellar cores, small gravitationally bound objects that are deeply embedded in interstellar filaments. The formation of the parental filament, as well as the condensation of cores out of these is a highly complex phenomenon. The gas dynamics is controlled by many physical processes, such as magnetic fields, turbulence, heating and cooling, radiation and (self-)gravity. The nonlinear coupling of these processes requires robust, highly resolved numerical simulations to study the detailled time evolution of all relevant quantities.

In this continuation project, we strive to deeper understand the dynamics within interstellar filaments that arise due to (proto-)stellar radiation, protostellar jets or bulk rotational motions (see Figs. 1 and 2). These processes are expected to significantly affect the chemical evolution within the filaments and their cores [1–3].

In Fig. 1 we show column density maps of two filaments from [5], where the filament line-mass exceeds the critical line-mass by a factor of ~ 1.5. The initial magnetic field is oriented parallel to the y-axis and is rather weak with $B_{\rm init} \sim 25 \,\mu {\rm G}$. The filament in the upper row is at rest, with only mildly supersonic turbulent fluctuations. At $t = 130 \, {\rm kyr}$, the filament has already broken up into individual overdensities. The surrounding lower column density gas reveals some substructure due to locally varying accretion of gas onto the filament. Since the magnetic field is perpendicular to the filament's long axis, the gas can collapse to the centre with almost no magnetic support. In case, the filament reveals some bulk

rotational pattern, it is primarily the more diffuse region surrounding the filament hub, which is affected. This is because the ratio of rotational and gravitational energy decreases rapidly in the central parts of the filament. We note that the initial condition for this ratio is only an average over the entire filament. Hence, only the outer parts are affected, and one can see two 'fronts', which are revealed by overdense material near the upper and lower boundary of the figure. Interestingly, the ridge of the filament still forms cores, though these appear less dense. In addition, the number of fragments is obviously reduced.

At late times (right panels), the amount of fragments has been reduced due to merging of these. The radial extent of the filament without rotation appears a little more extended due to self-generated dynamics along the ridge. In contrast, the rotation filament shows a rather homogeneous density distribution with some overdensities along the initial ridge. Please note that the radial extent of the entire structure (in the left indicated by the two fronts) has not changed dramatically. This indicates that the material is still bound to the innermost parts.

In Fig. 2 we show a temperature map of a star forming core as well as the stellar accretion rates as a function of time [4]. The age of the star in the temperature map is about 35 kyr. The effect of its radiation on the gas is rather concentrated to within a small volume surrounding the star. However, through low-density channels, radiation can escape and is able to heat up the gas at slightly larger distances. The temperatures near the star reach values up to $T \sim 1000 \,\mathrm{K}$, while the farther away regions reveal $T \sim 20 - 100 \,\mathrm{K}$. The gas at the edges of the depicted region still possesses its initial temperature of $T = 10 \,\mathrm{K}$.

In addition, we show the stellar accretion rates as a function of time. Both formed stars show rather similar accretion rates, but the one for the younger one reveals much more variations due to differences in the gas dynamics in their environment. These data indicate the importance of the initial conditions for the subsequent stellar evolution and the efficiency of the feedback processes. This, however, remains to be studied with safer statistics, i.e. more stars per filament.

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Figure 1: Surface density maps of two simulated filaments. Upper row: Supercritical filament without rotation. Bottom row: Rotating supercritical filament with an average ratio of rotational to gravitational energy of ~ 2 . Clearly, rotation only has a visible effect on the lower density material. Along the ridge of the filament overdensities can form independent of the degree of rotation. However, due to the rotational support of the gas, which is not located along the ridge, accretion onto the formed cores is less efficient. Note the increased filament width due to rotation.



Figure 2: Left: Temperature map of the core, which harbours the more massive star $(M \sim 2 M_{\odot})$. Overlaid are velocity streamlines in light-blue. Although the star is about 35 kyr old at this shown stage, its region of influence via its radiation is restricted to a few thousand AU at most. By identifying the streamlines, it becomes clear that in this core, accretion is not hampered by the stellar radiation. Accretion of matter onto the star appears to be isotropic. Left: Accretion rate as a function of time for two sources within the filament. Although stellar radiation seems to have only a spatially limited effect, it still continuously reduces the accretion rate of the stars. Please note the accretion bursts, identified by the temporary spikes. Note further the difference in the accretion rates during the early stages of evolution. Since the stars are well separated, these features arise due to the dynamics in the environment.

More Information

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